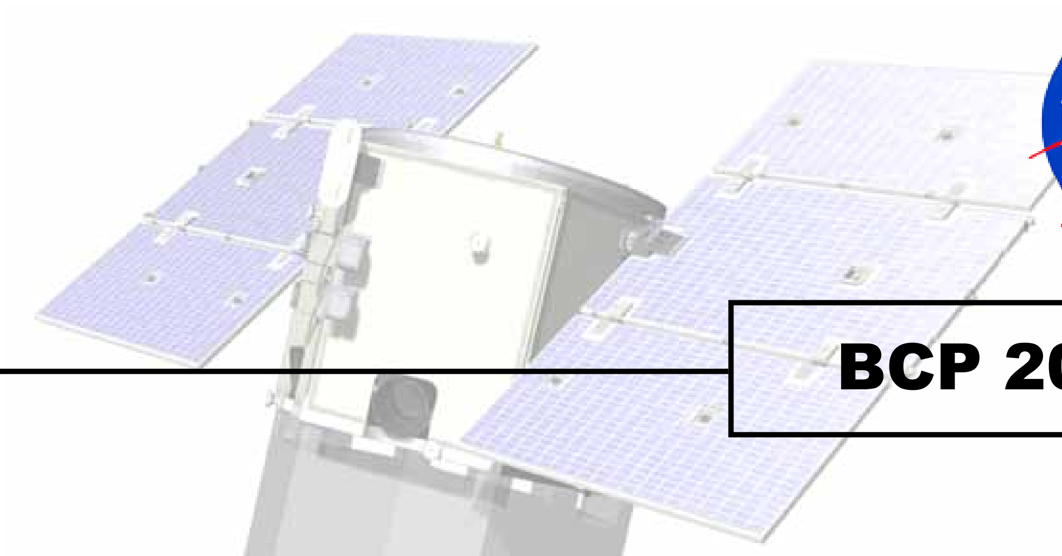


BCP 2000

The Ball Aerospace Rapid-III catalog core spacecraft is based on the ICESat spacecraft procured under NASA's Rapid Spacecraft Acquisition contract. ICESat was launched January 12, 2003 on a Delta II-7320 using a dual payload attach fitting and inserted into a 592 km, 94 degree inclination, exact repeat orbit. ICESat completed over 7 years of operation before its primary mission ended in 2010.

The Ball Aerospace Rapid-III core spacecraft, a Ball Commercial Platform (BCP) 2000, incorporates incremental design improvements from ICESat and other BCP 2000 implementations. It is a fully redundant design that provides a highly reliable platform (Ps >0.9 at 5 years) to protect missions from spacecraft failure. It has excellent pointing, agility, and data throughput capabilities that can be used to simplify missions and enhance data return.

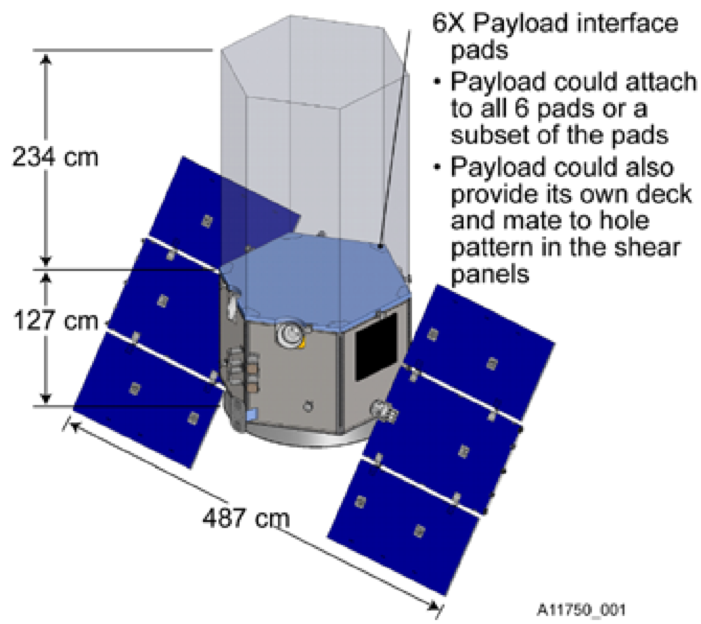
The BCP 2000 design has proven adaptability as shown in the table below. It has been configured to accommodate a variety of instruments and instrument suites, launch vehicles, ground segments, orbits, and mission profiles. The BCP 2000 is compatible with low-earth orbits from 400 to 900 km and most inclinations. This spacecraft is compatible with Delta II, EELV, Taurus XL, Taurus 2, Falcon 9, and Minotaur IV launch vehicles.

Structure and Mechanisms

Our compact spacecraft structure provides a large instrument volume and fits within the fairing dynamic envelope of candidate launch vehicles. A separate propulsion module interfaces with the spacecraft bus at a single bolted interface and a single electrical connection.

The hexagonal, bonded structure accommodates spacecraft components mounted on interior panels, enabling deployable solar array wings to be folded around the structure for launch on smaller launch vehicles. The external panel surfaces provide thermal radiator areas.

The single-axis drive solar array is a simple foldout panel design flight-proven on previous BCP 2000 missions.



Deployed Spacecraft. *Large payload volume supports instrument component mounting and FOV requirements with a minimum of incursions.*

Ball Aerospace & Technologies Corp.

Ball Aerospace & Technologies Corp. • 1600 Commerce St. • Boulder, CO 80301 • 303-939-6100 • Fax: 303-939-6104 • info@ball.com • www.ballaerospace.com

Parameter	Previous BCP 2000 Implementations for NASA				Rapid III Core Bus
	QuikSCAT	ICESat	CloudSat	NPP	
Observatory Mass	925 kg	958 kg	847 kg	2166 kg	1045 kg
Payload Mass	205 kg	302 kg	255 kg	650 kg	500 kg
Bus Mass (dry)	644 kg	580 kg	516 kg	1192 kg	450 kg
Fuel Mass	76 kg	76 kg	76 kg	324 kg	95 kg
Orbit Average Power (Required/Available)	506 W/892 W	696 W/825W	571W/822W	1424 W/1613 W	788 W/1045 W
Payload OA Power	210 W	350 W	346 W	608 W	400 W
Mission Life	2 yrs	5 yrs	3 yrs	5 yrs	5 yrs
Launch Vehicle	Titan II	Delta II	Delta II	Delta II	Multiple
Mission Data Rate	2 Mbps	40 Mbps	1 Mbps	300/10 Mbps	80 Mbps
Data Storage	8 Gbit x2	56 Gbit	2.2 Gbit	343 Gbits	56 Gbits
Telemetry Storage	64 Mbits	256 Mbit	256 Mbit	3.2 Gbits	3.2 Gbits
Pointing Knowledge (3-sigma) (realtime)	<0.02 deg	<0.006 deg	<0.02 deg	<0.004 deg	<0.004 deg
Pointing Control (3-sigma)	<0.02 deg	<0.006 deg	<0.02 deg	<0.01 deg	<0.006 deg
Position Accuracy	<30m	<<30 m	<30m	<30 m	<30 m
Delta-V	>125 m/s	152 m/s	170 m/s	>275 m/s	~200 m/s
EOL Solar Array Output	1025 W	1962 W	1228 W	2730 W	1845 W
Battery Capacity	40 Amp-hr	40 Amp-hr	40 Amp-hr	80 Amp-hr (x2)	66 A-hr

The range of performance achieved by the BCP 2000 systems built to date envelopes our core spacecraft's performance and demonstrates the ability of the BCP 2000 design to support a variety of mission unique requirements.

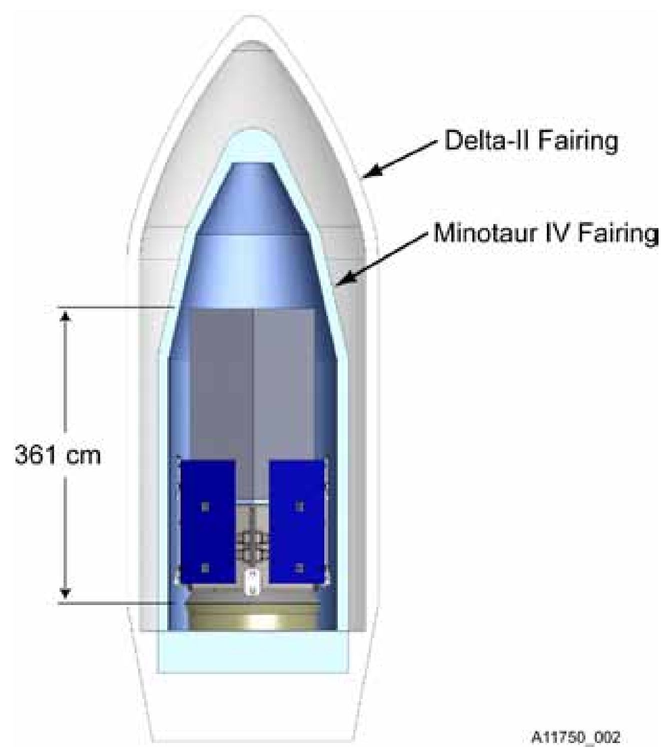
Electrical Power

The power and electrical subsystem uses the highly reliable BCP 2000 power system architecture that has been successfully used on many missions. The subsystem employs a switch regulated direct energy transfer system that transfers power generated from the Sun's energy directly to the Observatory's loads without the need for an intermediate power regulator.

Solar array power output is segmented to allow precise control of current supplied to the loads and the battery; the battery regulates the bus voltage.

Propulsion

The BCP 2000 uses a mono-propellant hydrazine system in a segregated module. The design consists of a single positive expulsion hydrazine diaphragm tank, propellant distribution (feed system) hardware, thrusters, and thermal control hardware. The subsystem is mounted on a dedicated structure and is an all-welded, modular construction that operates as a blowdown system. Four catalytic thrusters each provide 5.3N (1.2 lbf) thrust at BOL pressure and are canted to provide attitude control torques in all three axes.



Stowed Spacecraft. *Compact spacecraft bus allows for ample payload volume even in small launch vehicle fairings.*

Attitude Control

The BCP 2000 employs a three-axis stabilized system using reaction wheels as the primary control actuators and star trackers, an IRU, and GPS as primary sensors. The system also employs Sun sensors and magnetometers to complement the primary sensors and provide data in fault/safe mode, magnetic torque rods for backup control authority and momentum management, and propulsive thrusters for orbit attainment and maintenance.

A zero-momentum control system provides precise control torques and momentum storage. Electromagnets manage Observatory momentum in the presence of external disturbance torques. The system can operate on any three of the four wheels for redundancy management. Star trackers provide precise attitude determination and when combined with data from the GPS and SSIRU, provide precise geolocation. To simplify calibration, flight algorithms are fully table-driven, allowing all sensor, actuator, attitude control, and attitude determination coefficients to be adjusted on-orbit to optimize performance.

Command and Data Handling

These functions are performed by a block redundant Spacecraft Control Computer (SCC), redundant Precision External Clock (PEC), and internally redundant Command and Telemetry Unit (CTU) and Solid State Recorder (SSR) components.

Command and Data Handling (C&DH) supports the upload of new flight software to the SCC on-orbit. The SCC provides two 1553 bus controllers – one dedicated to the payload interface and the other used for spacecraft functions such as star tracker and SSIRU communications.

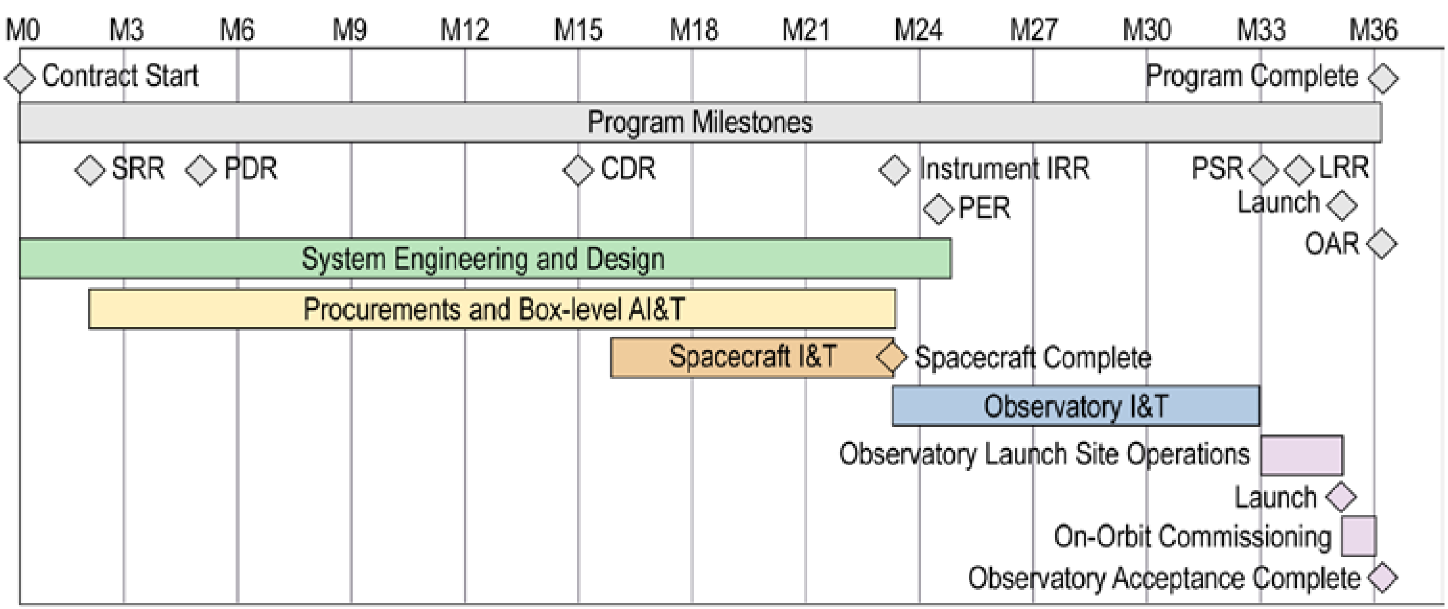
The CTU provides the bulk of the C&DH command and telemetry functions. This redundant device inputs and decodes real-time and stored commands and outputs high-level discrete commands or serial digital commands to other spacecraft subsystems. It also collects data from analog, digital, and thermistor telemetry points, and formats them into a serial digital data stream. This stream is then formatted into CCSDS-compatible frames, and sent to the transmitter for downlink to the ground or stored in the CTU. The core spacecraft SSR is an internally redundant unit with a total storage capacity of 56 Gbits.

Communication

This subsystem provides the interface between the Observatory and the ground segment. A STDN compatible command uplink and telemetry downlink is provided via redundant transponders. The command uplink receives real-time and stored commands as well as software table loads from ground stations. A high rate payload downlink consists of redundant X-band transmitters. An 80 Mbps implementation using OQPSK modulation is the baseline for the core spacecraft.

Thermal Control

The BCP 2000 provides temperature control and stability tailored to meet the specific needs of the payload and spacecraft components using reliable and proven techniques such as thermal isolation and individualized heater control with programmable set points. Thermal control uses passive design techniques such as MLI, standard thermal control surfaces, and thermal isolation. The payload is normally thermally isolated from the spacecraft with isolating mounts and MLI.



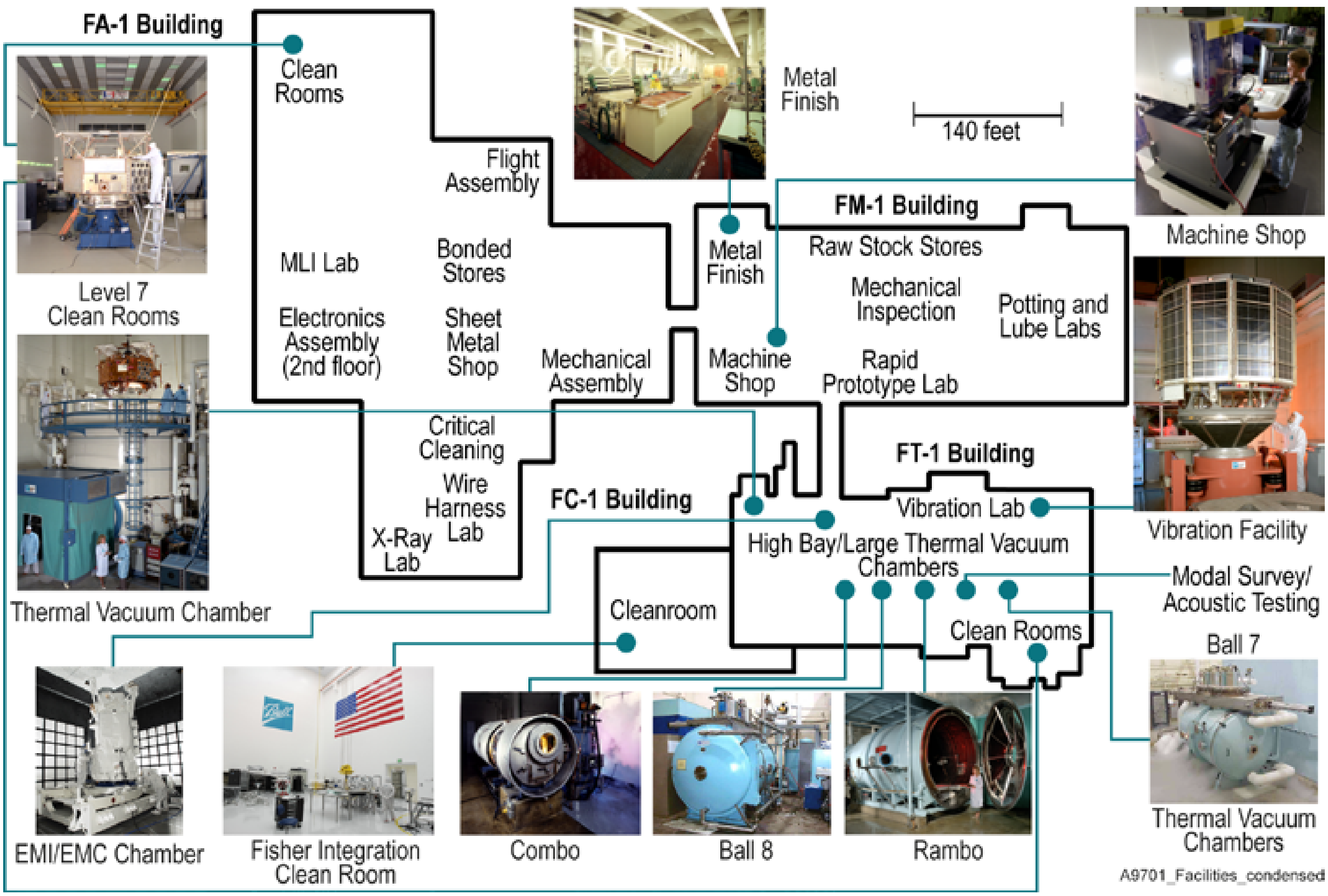
The typical Rapid III program is a 36-month program which includes two months of schedule margin and a one-month commissioning phase.

Flight Software

Flight software has extensive on-orbit heritage and runs on a 133-MHz BAE Rad750 PowerPC single-board computer with 128 MB of RAM and 12 MB of EE-PROM. Flight software interfaces with spacecraft command and data handling and attitude control hardware, and the payload.

Facilities

As an end-to-end producer of space systems, Ball Aerospace has all of the development and production facilities required for the design, production, assembly, integration, and test of components, spacecraft, space instruments, and fully integrated observatories. Ball Aerospace facilities accommodate instrument needs from initial delivery, through integration with the spacecraft, and on to integrated system-level testing.



Additional mission specific capabilities are available from our BCP spacecraft line.

Item	Capability
Data storage	2 terabits
Downlink transmission rate	800 Mbps
Agility with CMGs (typical – inertia dependent)	4.5 deg/sec 2 deg/sec^2
High speed data interfaces	IEEE-1394, LVDS
Propellent capacity	320 kg
Solar array configuration	Wide variety

Rapid Spacecraft Development Office (RSDO)

NASA Goddard Space Flight Center
Mail Code 401.1
Greenbelt, MD 20771 USA
Phone: 301-286-1289
Email to: rsdo@rsdo.gsfc.nasa.gov